NOTES ON SOME PROBLEMS OF ADAPTATION.

3. The Volume of Water Involved in the Cloacal Pumping of Holothurians (Stichopus).[1]

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It has been of interest, especially in connection with studies of respiration, to determine the volumes of seawater which various marine animals pass through their respiratory organs. With the sponge *Spinosella* Parker ('14) calculated from his measurements that something like 78 liters a day was the volume forced through a single "finger" of the body of this sponge. For *Ascidia,* Hecht ('16) showed that the branchial stream was probably somewhat in excess of 173 liters per day, in individuals of medium size. The water current in such cases (the only ones of the kind carefully investigated) brings not only oxygen but food particles as well, and in addition has an excretory significance.

I undertook to measure the volume of seawater involved in the cloacal pumping of a holothurian such as *Stochopus mœbii,* in which water is forced into respiratory trees and then expelled to the exterior. The cloacal chamber of *Stichopus* pulsates with a frequency which depends on the size of the animal; after a certain number of pulsations the water contained in the respiratory trees is forced out; the number of pulsations between two acts of "spouting" also depends on the size of the individual (cf. Crozier, '16). As in all such cases, the expelled water is forced out rather violently, driven to a considerable distance, so that it is not readily taken in again when inspiration is again begun (Hecht, '16; Arey and Crozier, '19).

By previously ascertaining the mean number of inspiratory pulsations elapsing between "spoutings," it was possible to remove a given *Stochopus* from the water just before the beginning of an expiratory act, and to receive the discharged water in a funnel

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leading to a graduated cylinder. Employing 10 individuals each 24–25 cms. in length, I found an average volume of 15.5 c.c. of of seawater to be expelled in this way.

If a cut through the body-wall be made rapidly around the body of a *Stichopus* at the level of the anterior end of the cloacal chamber (Crozier, '16), it is possible to obtain a preparation in which the respiratory trees remain intact and preserve their normal connection with the cloacal wall. Such a preparation will live for a long time in seawater, and it can be seen that water is pumped, as normally, into the respiratory trees, and that when these organs have been expanded to a certain degree their contained water is expelled in the usual manner. In this process the respiratory trees themselves are actively contractile (cf. Iwanzoff, '97; Henri, '03); they shrivel up almost, but not quite, completely —so that nearly all their contained water is expelled. The independent nature of the activity of the cloaca and respiratory trees affords a curious instance of the autonomy of the organs in echinoderms.

Examination of the interior of an intact *Stichopus* at the conclusion of "spouting" showed that the respiratory trees were in this case also almost completely contracted.

The cloacal chamber of *Stichopus* 24.5 cm. in length pulsates with a frequency of 9.6 per minute (at 27°), and 8 or 9 inspiratory pulsations intervene between two expirations, each of the latter occupying some 12 seconds (cf. Crozier, '16). On this basis a *Stichopus* of this size will (at 27°) take into its cloaca about 15.5 c.c. of water during each 65 seconds, or about 859 c.c. per hour; leading to an estimated amount of 20–21 liters per day, assuming a uniform rate during the 24 hours.

From the comparative standpoint, it must be remembered that probably little or no food-getting is associated with the entrance of water into the body of *Stichopus* by way of the cloaca, Pütter's ('07) notion to the contrary notwithstanding; but that, in contrast to the situation in sponges and in ascidians, respiration and excretion are in holothurians the sole functional implications of the water stream. In this way it can be understood that the volume of water required by these animals is much less, even in proportion to their size, than is the case with sponges, lamellibranchs, or ascidians.

The respiratory value of the water moved by the cloacal pump is clearly evidenced by this fact: seawater in which a *Stichopus* was living had a reaction of p_H 8.2; the p_H of the water expelled during spouting was 7.8; that of the fluid within the body-cavity, 7.6. It is obvious that even within a minute's time relatively considerable quantities of CO_2 are able to diffuse across the thin membraneous wall of the distended respiratory trees. According to Winterstein ('09) about 50 per cent. of the respiratory loss of CO_2 is accomplished through the "trees."

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